Will the insulated-tip radiofrequency catheter transform ablation procedures?

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Abstract

Radiofrequency (RF) ablation has been the most widely employed energy source for catheter ablation to date. However, most of conventional RF ablation energy dissipates into the bloodstream before reaching the target tissue. Technology that conveys RF energy exclusively toward target tissue may potentially improve the quality, safety, and outcome of the RF ablation procedures. RF ablation using a novel insulated-tip catheter (SMT, Sirona Medical Technologies, Windsor, CT) may refine RF ablation in the future to minimize the risk of iatrogenic complications. Although it is still unclear whether the results of the SMT catheter can be translated to a human beating heart, the data for SMT catheter of this study are very promising.

Editorial

Will the insulated-tip radiofrequency catheter transform ablation procedures?

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Keywords

Radiofrequency ablation, lesion formation, contact force, insulated-tip catheter

Radiofrequency (RF) ablation was initially proposed by Huang et al. in 1985 and has been the most widely employed energy source for catheter ablation to date (1-2). RF ablation transfers electromagnetic energy into thermal energy by a process called resistive heating at the surface of tissue (3). Meanwhile, the efficiency of RF energy application is highly affected by multiple factors, including power, duration, electrode contact area, and contact force. Catheters have continuously evolved over the past decades with the goal of delivering RF energy with greater safety and efficiency. The ideal catheter would create reproducible, reliable lesions while eliminating the risk of steam pops, perforation, or collateral damage to surrounding tissue. A major advancement has been the development of irrigated and contact force sensing catheters, which has improved the safety and efficiency, and perhaps the effectiveness of catheter ablation procedures. (4). Even with good contact using high-power setting, most of conventional RF ablation energy dissipates into the bloodstream before reaching the target tissue, which is called convective cooling (5). Convective cooling is the major thermodynamic factor opposing the transfer of thermal energy to deeper tissue layers. In response to these opposing forces, higher power and longer duration of RF energy is often applied. However, it also increases the risk of unfavorable complications, steam pop and coagulum. Technology that conveys RF energy exclusively toward target tissue may potentially improve the quality, safety, and outcome of the RF ablation procedures.

A novel ablation catheter with an insulated tip

In this issue of the Journal of Cardiovascular Electrophysiology, Aryana et al. (6) evaluated the outcome of RF ablation using a novel insulated-tip catheter (SMT, Sirona Medical Technologies, Windsor, CT) versus a conventional RF ablation (RFC) in silico, ex vivo (n=267) and in vivo (n=81) using porcine model. Briefly, the SMT ablation catheter is an open-irrigated ablation catheter with a novel design that consists of a central electrode, surrounded by 4 peripheral electrodes for both RF and pulse field ablation. The design is intended to insulate the central electrode which is surrounded by an insulating dielectric as well as a flexible metallic braid. The key concept of this catheter is to minimize the passage of RF energy into the bloodstream and the surrounding tissue and to focus a greater magnitude of the delivered energy into the targeted tissue directly. It does this by creating a Faraday cage by virtue of insulating the central electrode which is surrounded by an insulating dielectric as well as a flexible metallic braid. Further, the ablation catheter can be deployed and used in 'vector' or 'linear' configurations. The vector configuration intended to provide greater catheter stability and tissue contact during ablation procedure by using the four flexible wings as a "landing gear". Although the catheter is capable of both RF or pulse field ablation, only RF was evaluated in this study.

In this study, RF ablation using SMT proved capable of directing 66.8% of the RF energy into the targeted tissue, while RFC only 13.7% by analysis of computational model (in silico). This was further validated by the evidence from the ex vivo and in vivo studies. Low power-low irrigation (8-12W, 2ml/min) RF ablation using SMT is capable of creating lesions comparable in size to those with RFC at 30W, but with significantly greater impedance drops. On the other hand, high power-high irrigation (15W, 20ml/min) RF ablation using SMT can yield lesions that are significantly larger and deeper than with RFC at 30W. RF ablation using SMT was consistently associated with lower incidence of steam pop both ex vivo and in vivo study. Of note, lesions created with SMT were more homogenous and sharper transition zones than those created with RFC.

The results of the study by Aryana et al. provide novel evidence supporting the effectiveness of RF ablation using SMT catheter. Clinical importance of RF application is how efficiently can RF energy be transferred directly to the target tissue without causing unfavorable complications. In that meaning, SMT may be superior to RFC based on the result of this study that approximately 67% of the RF energy directly into the target tissue, requiring lower power to create comparable lesions provided by RFC. Considering the structure and mechanism of SMT, RF ablation using SMT reduces the opposing force (convective cooling) and improves the catheter stability when used in 'vector' configuration. As a result, power and duration of energy delivery can be reduced, which leads to a lower likelihood of complications such as steam pop and coagulum formation. The uniform and homogeneous lesion formation of SMT is also of critical importance during ablation procedures since non-uniform and heterogenous ablation lesions may lead to arrhythmia recurrence or in the worst case, iatrogenic arrhythmias. The findings of this study provide hope that the insulation technology may refine RF ablation in the future to minimize the risk of iatrogenic complications.

The main question is whether these promising results support the idea that SMT should be used in clinical practice. The significant limitation of this study is that it is only confirmed by animal experiments under the fixed setting. All RF ablation lesions were created with perpendicular orientation to the tissue with preset power and irrigation flow, which are high power-high irrigation (15W, 20ml/min) and low power-low irrigation (8-12W, 2ml/min). The effect of varying orientations in a beating heart, and of varying tissue architecture remain unknown.

During RF energy application, a myriad of factors should be considered in addition to traditional ablation indices of power and RF duration. For example, catheter orientation, catheter stability, and tissue thickness (tissue architecture) also play an important role in determining RF ablation lesion formation. Recently, modification of irrigation flow rate has been proposed to assist in altering geometry. Open irrigation can change lesion geometry such that the maximal lesion width, corresponding to the depth of hottest tissue temperatures. This is particularly relevant for thin-walled structures such as posterior left atrium that lie in close proximity to structures vulnerable to collateral injury such as the esophagus (7).

Another important concern is the contact force. In this study, contact force was not described since control experiments were only conducted using the ThermoCool RFA catheter. It is well accepted that contact force is a key determinant of lesion size, volume, and depth (8). The optimal contact force required to make transmural lesions has been examined in animal models. Transmural lesions at cavotricuspid isthmus (CTI) of swine were seen with average contact force >20g but never with contact force <10g (mean depth 0.75mm) (9). Further, a number of studies demonstrated that contact force sensing reduced procedural and fluoroscopy time, improved impedance falls, reduced RF ablation time when compared with non-CF sensing catheters (10). The results of these studies potentially suggest the importance of contact quality. Shah et al. demonstrated that constant compared with variable and intermittent contact resulted in greater lesion size (11). A lower average contact force made it more likely that contact was intermittent, with 51% lesions exhibiting diastolic loss of contact force (0g) if the average contact force was <4g compared with 3% if average contact force was >20g (12).

For a comprehensive interpretation of ablation lesion formation by using SMT, the effects of these factors need to be verified in addition to power and duration of energy delivery. Although it is still unclear whether the results of the SMT catheter can be translated to a human beating heart, the data for SMT catheter of this study are very promising. We eagerly await further studies to validate with comprehensive factors and show if this technology can be clinically applicable. For the moment, however, the authors ought to be congratulated for an important advance in ablation technologies using elegant computational, ex-vivo and in-vivo experimental work.

Conflict of interests

The authors declare that there are no conflicts of interest.

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